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The Oligocene Noda Flora from the Yuya-wan Area of the Western End of Honshu, Japan. Part 1

By

Toshimasa TANAI and **Kazuhiko UEMURA**

Department of Geology, National Science Museum, Tokyo

Abstract Taxonomic reinvestigation was made for Oligocene plant megafossils from the upper part of the Kiwado Formation in Yamaguchi Prefecture. The plant assemblages, called the Noda flora, are composed of one species of conifer and 33 species of dicotyledons, distributed in 19 families and 26 genera. Four species among the 34 taxa are described as new species: *Quercus nagatoensis*, *Rhododendron hekiense*, *Rosa okamotoi* and *Lagerstroemia imamurae*. Although most of the plant fossils are poorly preserved, these fossils from the Kiwado Formation provide a basis for Late Oligocene floral sequence in East Asia.

Introduction

The Tertiary Hioki Group, exposed in the Yuya-wan (bay) area of Yamaguchi Prefecture, is mostly neritic and partly fluvio-lacustrine in origin, and contains marine invertebrates, plants and other fossils. The plant-bearing beds occur at three horizons of the Hioki Group. OKAMOTO and IMAMURA (1964) listed plant megafossils, which were determined by the late Dr. S. ENDO, from the three horizons to discuss the age of the Hioki Group. Of their collection the assemblages of the upper horizon, called the Daibo flora, were only described in detail by HUZIOKA (1974).

The Hioki Group was considered to be ranged from the Late Oligocene to the Early Miocene by OKAMOTO and IMAMURA (1964), based on paleontologic discussion. HUZIOKA (1974) concluded that the Daibo flora belongs to the Daijima-type of late-Early Miocene age. The *Engelhardia*-bearing flora of the lower horizon in the Group was asserted to be of Late Oligocene age by our preliminary study (TANAI and UEMURA, 1983). Recent works of planktonic microfossils on the coeval Ashiya Group of North Kyushu (SAITO and OKADA, 1984; TSUCHI et al., 1987; OKADA, 1991) suggested that the Hioki Group is older than the Miocene. Thus the Hioki Group may provide a sequence of Oligocene floras that have been poorly known in East Asia.

One of us (TANAI) visited the Yuya-wan area in 1971 and 1776, but failed to collect enough fossil specimens to discuss the floral sequence. Recently Drs. IMAMURA and OKAMOTO kindly offered us a part of their collection to our study. Although several specimens are fragmentary and are poorly preserved, it is important for Tertiary floristic and vegetational history of Japan to describe the floral sequence of the Hioki Group. It is the principal subject that the Noda flora, the assemblage

of middle horizon of the Group, is described in their floral composition. As part of the present study, we present systematic description of the Noda floral components.

We are especially grateful to Dr. Sotoji IMAMURA and Dr. Kazuo OKAMOTO for their kind offers of the valuable specimens. Thanks are also due to Dr. Katsuhiro KIMURA for helpful discussion, and Dr. Ienori FUJIYAMA for donating some plant fossils from the Kiwado Formation. The study is supported in part by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture (01540682; Uemura).

Geologic Setting

The geologly of the Yuya-wan area was described in detail by OKAMOTO and IMAMURA (1964). They classified Tertiary sediments into two groups, the lower the Hioki and the upper the Yuya-wan (Table 1). The Hioki* Group unconformably rests on the Paleogene volcanics and is covered by the Yuya-wan Group which consists of Middle Miocene marine formations (OKAMOTO and IMAMURA, 1964; OKAMOTO, 1965). Subsequently, OKAMOTO (1970, 1975) redefined the subdivisions of the Hioki Group and divided it into the Jyuraku, Kiwado, Taoyama and Hitomaru formations in ascending order. The Jyuraku and Hitomaru formations consist mainly of coarse clastic sediments and are belived to have been deposited in nonmarine (fluvio-lacustrine) environments. The middle part of the Hioki Group, Kiwado and Taoyama formations, is mostly made up of sandstone, shale and their alternating beds. The Kiwado and Taoyama formations yield rich neritic molluscan fossils called the Ashiya fauna (OKAMOTO, 1965; FUSE and KOTAKA, 1986). Tuffs and tuffaceous rocks are commonly found throughout the Hioki Group. Tuff in the uppermost part of the Kiwado Formation has the fission track age of 24.5 Ma (KIMURA & TSUJI, 1990). Volcanic rocks of the Tsuo Andesite and Imamisaki Basalt unconformably underlying the Hioki Group, have also been dated as 35.0 Ma (fission track age) and 35.4 Ma (K/Ar age), respectively: namely, the earliest Oligocene (MURAKAMI et al., 1989; IMAOKA and ITAYA, 1989).

Plant megafossils are found at three horizons of the Hioki Group; the Jyuraku, Kiwado and Hitomaru formations. The plant megafossil assemblages from the latter two formations are known as the Noda (IMAMURA, 1958; OKAMOTO and IMAMURA, 1964) and Daibo (OKAMOTO and IMAMURA, 1964; HUZIOKA, 1974) floras, respectively. The Jyuraku Formation also yields plant megafossils such as *Pinus*, *Engelhardia* and evergreen oaks (OKAMOTO and IMAMURA, 1964; TANAI and UEMURA, 1983). Among these assemblages, the Daibo flora has only been described in detail by HUZIOKA (1974). Apart from plant megafossils, TAKAHASHI (1963a, b) described palynofloras from the Kiwado and Hitomaru formations.

* The valid geographic name is now "Heki". OKAMOTO and IMAMURA (1964) used "Hioki" when describing the Group, which therefore has priority (see also OKAMOTO, 1975). In this paper, "Hioki" will be used here in reference to the stratigraphic unit and "Heki" to geographic name.

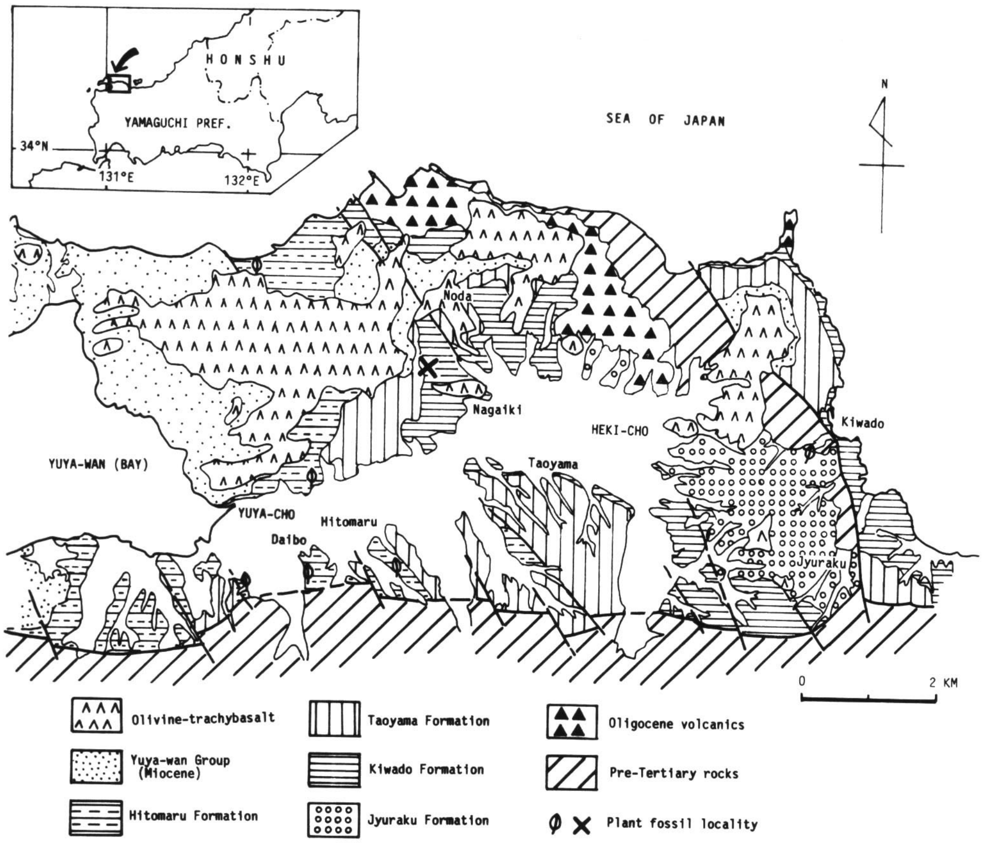


Fig. 1. Map showing generalized geology (OKAMOTO and IMAMURA, 1964; OKAMOTO, 1975) and plant megafossil localities in the Yuya-wan area.

Our present study is based largely on the collection by S. IMAMURA and K. OKAMOTO collected at a point between Noda and Nagaiki: 1 km northwest of Nagaiki in Heki-cho, Otsu-gun (Fig. 1). Plant megafossils were collected from the upper part of the Kiwado Formation: sandy shales below the 20 m thick tuff layer of the uppermost part of the Formation (OKAMOTO and IMAMURA, 1964, p. 8). Additional plants are also studied, which were collected by us and I. Fujiyama from nearly the same point of OKAMOTO and IMAMURA (1964). These fossils are all leaf imprints which are mostly fragmentary and poor in preservation of fine venation.

Systematic Descriptions

Described herewith are 33 plants, distributed among 19 families and 25 genera. Except for one conifer, the remaining taxa are woody dicotyledons. All the specimens

Table 1. Stratigraphy of Yuya-wan area (OKAMOTO and IMAMURA, 1964; OKAMOTO, 1975).

		Olivine-trachybasalt (Miocene)	
		unconformity	
		Yuya-wan Group (Middle Miocene)	Yatsuo-Kadonosawa fauna
		unconformity	
Hioki Group (Oligocene)	Hitomaru Formation (500 m)	sandstone, intercalated with conglomerate, tuff & shale	*Daibo flora* non-marine molluscs
	Taoyama Formation (420 m)	sandstone & shale, intercalated with tuff	Ashiya fauna
	Kiwado Formation (200 m)	conglomerate & sandstone, with shale & tuff	Ashiya fauna *Noda flora*
	Jyuraku Formation (260 m)	conglomerate & sandstone, intercalated with shale & tuff	*Plants*
		unconformity	
		Tsuo Andesite and Imamisaki Basalt (Oligocene)	
		unconformity	
		Pre-Tertiary rocks	

are deposited in the Paleobotanical Collections, Department of Geology, National Science Museum, Tokyo (NSM-PP).

Family Taxodiaceae

Genus ***Glyptostrobus*** ENDL.

Glypostrobus europaeus (BRONGNIART) HEER

(Pl. 1, fig. 1)

Glyptostrobus europaeus (BRONGNIART) HEER. 1855. Fl. Tert. Helv. I, p. 51, pl. 19, figs. 1–6; pl. 20, figs. 1a-f.

Collection: NSM-PP 10363.

Family Lauraceae

Genus ***Lindera*** THUNB.

Lindera sp.

(Pl. 1, fig. 7)

Discussion: The specimen has the distinct fimbrial vein and weak basal secondary

veins that are characteristics of some Lauraceae leaves. The elliptic shape and irregularly-spaced, camptodromous secondary veins enclosing tertiary arches indicate that this incomplete leaf is similar to *Lindera* such as *L. glauca* (SIEB. et ZUCC.) BL. and *L. umbellata* THUNB., especially to the former.

Collection: NSM-PP 10364.

Genus ***Litseaphyllum*** WOLFE

Litseaphyllum sp.

(Pl. 1, fig. 8)

Discussion: Small lanceolate leaves have weak secondary veins diverging from the primary vein at acute angles; these features are found in some lauraceous leaves such as *Persea*.

Collection: NSM-PP 10402.

Family Berberidaceae

Genus ***Berberis*** L.

Berberis saseboensis TANAI

(Pl. 1, fig. 6)

Berberis saseboensis TANAI. 1961. J. Fac. Sci. Hokkaido Univ., [4], 11: 351. pl. 21, figs. 4, 6.

Discussion: The spatulate shape, entire margin, and irregularly spaced camptodromous secondary veins indicate that these small leaves are identical to *Berberis saseboensis* of the Sasebo coal field, though the leaves are somewhat variable in shape and size. These leaves are commonly found in the Kiwado Formation as in the Ainoura Formation of Kyushu.

Collection: NSM-PP 10365.

Family Cercidiphyllaceae

Genus ***Cercidiphyllum*** SIED. et ZUCC.

Cercidiphyllum sp.

(Pl. 3, fig. 6)

Discussion: The small specimen has features of *Cercidiphyllum*: basal-actinodromous venation and crenato-serrate margin with glandular tipped teeth. It is probably referable to *C. palaeojaponicum* Endo which is common in the Paleogene of northern Japan.

Collection: NSM-PP 10366.

Family Hamamelidaceae

Genus ***Hamamelis*** L.

Hamamelis sp. cf. ***H. protojaponica*** TANAI et N. SUZUKI

(Pl. 1, fig. 3; pl. 4, fig. 7)

cf. *Hamamelis protojaponica* TANAI et N. SUZUKI. 1965. Palaeont. Soc. Japan, Spec. Paper (10): 27, pl. 5, fig. 3b; pl. 17, fig. 4.

Discussion: The rhombic shape, asymmetric base, craspedodromous secondary veins diverging at narrow angles, and basal secondary veins joining with petiole beyond leaf base, are features of some genera of Hamamelidaceae. The feature that the ab-medial tertiary veins from basal secondaries are mostly craspedodromous indicates that these fossil leaves are referable to *Hamamelis*. The fossils are closely related to the extant *H. japonica* SIEB. & ZUCC. of Japan.

Collection: NSM-PP 10367, 10368.

Genus ***Liquidambar*** L.

Liquidambar sp. cf. ***L. miosinica*** HU et CHANEY

(Pl. 1, fig. 2)

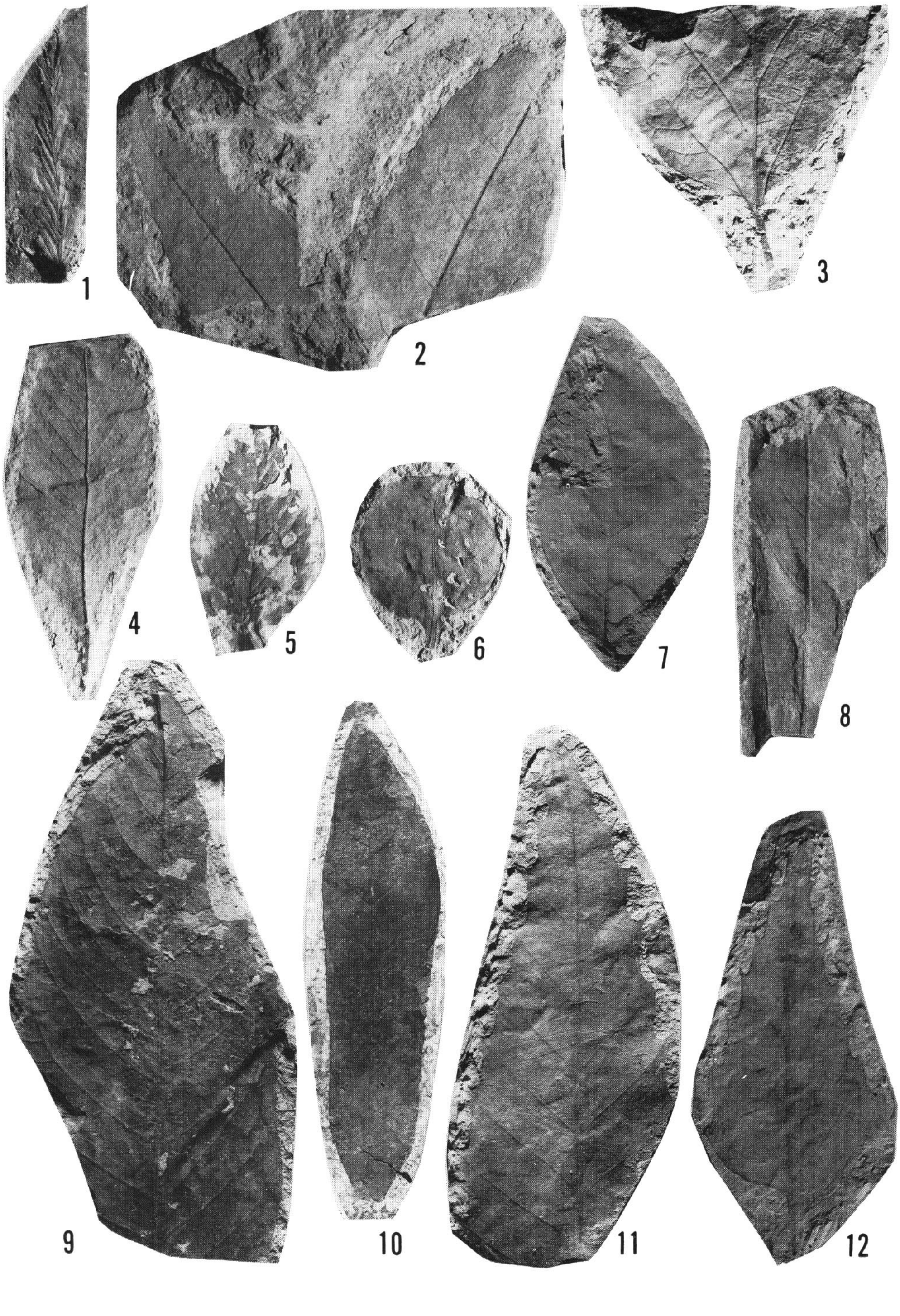
cf. *Liquidambar miosinica* HU et CHANEY, 1938. Palaeont. Sinica, [A], (1): 46, pl. 23, figs. 1, 2.

Discussion: A single fragmentary leaf is referable to *Liquidambar* by the adapically incurved teeth with glandular tips, camptodromous secondary veins, and camptodromous or craspedodromous marginal tertiary veins. This fossil leaf resembles *L. yabei* (MORITA) HUZIOKA of the Daibo flora in having narrow oblong lobes, but differs in wider extension angles of lateral lobes. The fossil may represent a slender leaf of *L. miosinica* HU et CHANEY, which is common in the Miocene of East Asia.

Collection: NSM-PP 10369.

Plate 1. (All figures in natural size unless otherwise stated)

Fig. 1. *Glyptostrobus europaeus* (BRONGNIART) HEER, NSM-PP 10363.
Fig. 2. *Liquidambar* sp. cf. *L. miosinica* HU et CHANEY, NSM-PP 10369.
Fig. 3. *Hamamelis* sp. cf. *H. protojaponica* TANAI et N. SUZUKI, NSM-PP 10367.
Fig. 4. *Ulmus longifolia* UNGER, NSM-PP 10370.
Fig. 5. *Carpinus* sp., NSM-PP 10380.
Fig. 6. *Berberis saseboensis* TANAI, NSM-PP 10365.
Fig. 7. *Lindera* sp., NSM-PP 10364.
Fig. 8. *Litseaphyllum* sp., NSM-PP 10402. ×1.4.
Fig. 9. *Lithocarpus* sp., NSM-PP 10373.
Fig. 10. *Quercus nagatoensis* TANAI et UEMURA, holotype NSM-PP 10376.
Figs. 11, 12. *Quercus miovariabilis* HU et CHANEY, NSM-PP 10374, 10375.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Family Ulmaceae

Genus *Ulmus* L.

Ulmus longifolia UNGER

(Pl. 1, fig. 4)

Ulmus longifolia UNGER, 1847. Chlor. Prot., p. 101, pl. 26, figs. 5, 6.

Collection: NSM-PP 10370.

Ulmus sp. cf. ***U. carpinoides*** GOEPPERT

(Pl. 2, figs. 7, 9)

cf. *Ulmus carpinoides* GOEPPERT, 1855. Tert. Fl. Schoss. Schlesien, p. 28, pl. 13, figs. 4–8; pl. 14, fig. 1.

Discussion: The leaves under the name of *U. carpinoides* have been reported from the Miocene rocks in Japan. They are apparently heterogenous including various species of *Ulmus* and also betulaceous species in some cases, and taxonomic revisions for this type of leaves are required.

Collection: NSM-PP 10371, 10372.

Family Fagaceae

Genus *Lithocarpus* BL.

Lithocarpus ? sp.

(Pl. 1, fig. 9)

Discussion: The thick texture, well-defined craspedodromous secondary veins enclosing tertiary arches, and percurrent tertiary veins being simple or forking indicate that this incomplete leaf is referable to *Lithocarpus* or *Castanopsis*, especially to the former.

Collection: NSM-PP 10373.

Genus *Quercus* L.

Quercus miovariabilis HU et CHANEY

(Pl. 1, figs. 11, 12)

Quercus miovariabilis HU et CHANEY, 1938. Palaeont. Sinica, [A], (1): 36, pl. 15, figs. 5, 6.

Discussion: Fossil leaves of *Quercus* and *Castanea* from the Lower and Middle Miocene of East Asia have been confused in their taxonomy. Especially, dentate margined leaves with spiny teeth have been referred to *Castanea miomollissima* HU et CHANEY, *C. ungeri* HEER, *Quercus miovariabilis* HU et CHANEY and *Q. sinomiocenicum* HU et CHANEY by many authors; however, their generic or specific diagnoses are obscure for distinction. HU and CHANEY (1938) described that the percurrent tertiary veins of *C. miomollissima* are not close in the intercostal areas and form loops along

the margin while those of *Q. sinomiocenicum* are closely spaced. However, they failed to clarify the definite distinction of venation features between *Q. miovariabilis* and *Q. sinomiocenicum* except for difference of basal shape.

Leaves of the extant *Castanea* have usually the tertiary venation features as pointed by HU and CHANEY (1938). *Q. sinomiocenicum* and *Q. miovariabilis* closely resemble both leaves of *Q. variabilis* Blume and *Q. acutissima* Carr. living in East Asia; these two extant species are distinguished only by distance of intercostal tertiary veins, except for the hairs of undersurface. Judging from the original figures, *Q. sinomiocenicum* is closely related to the extant *Q. acutissima* in having closely spaced tertiary veins (about 1 mm distance), but tertiary vein features of *Q. miovariabilis* are obscure in the original description and illustrations. Unfortunately, all the holotype specimens of *Castanea* and *Quercus* described by HU and CHANEY have been lost in Nanjing.

Most of the Noda specimens here discussed, are closely similar to *Q. miovariabilis* in narrow oblong shape, and some of them resemble *C. miomollissima* in wider shape. These specimens are too poor in preservation of tertiary venation to determine the above-noted taxonomic problem. Thus, these Noda specimens are tentatively referred to *Q. miovariabilis*.

Collection: NSM-PP 10374, 10375.

Quercus nagatoensis TANAI et UEMURA, sp. nov.

(Pl. 1, fig. 10)

Typus: Holotype NSM-PP 10376; Noda, Heki-cho, Yamaguchi Pref.; Kiwado Formation (Late Oligocene).

Diagnosis: Leaf lanceolate, gradually narrowed at apex, cuneate at base, 7.3 cm long (estimated) and 1.8 cm wide; margin entire, markedly revolute; petiole missing. Venation pinnate; midvein thick, straight; secondary veins 13 pairs, diverging at wider angles on apical part than on lower and middle parts, gently curving up, forming broad loops just within the margin; tertiary veins coarsely reticulate; 4th and 5th order veins forming areolation; areoles 4 or 5 sided, small (0.2–0.3 mm across); freely ending veinlets lacking or single.

Discussion: The thick texture, revolute margin and small distinct areoles are characteristics of evergreen oaks (*Cyclobalanospsis*). This fossil leaves, having entire margin and reticulate tertiary venation (not percurrent), are closely related to the extant *Q. bambusifolia* HANCE and *Q. hui* CHUN of southern China.

Collection: Holotype NSM-PP 10376.

Family Betulaceae

Genus ***Alnus*** Mill.

Alnus prenepalensis HU et CHANEY

Fig. 2. Venation of *Alnus praenepalensis* HU et CHANEY. NSM-PP 10377.

(Pl. 2, figs. 2, 3; Fig. 2)

Alnus prenepalensis HU et CHANEY, 1938. Palaeont. Sinica, [A], (1): 30, pl. 10, figs. 1, 4, 6. —TANAI, 1961. J. Fac. Sci. Hokkaido Univ. [4], 11: 281, pl. 7, fig. 3.

Hydrangea lanceolimba HU et CHANEY, 1938. Palaeont. Sinica, [A], (1): 50, pl. 25, figs. 5, 6. —TANAI, 1961. J. Fac. Sci. Hokkaido Univ. [4], 11: 341, pl. 25, fig. 11a.

Hydrangea miobretschneideri auct. non HU et CHANEY. TANAI, 1961. J. Fac. Sci., Hokkaido Univ., [4], 11: 341, pl. 25, fig. 11b.

Discussion: Although the fossil leaves are somewhat variable from ovate to broadly ovate in shape and from broadly cuneate to rounded at base, they are characterized by the following features: the secondary veins are typically camptodromous but sometimes semicraspedodromous; a branch from the secondary arch ends in sinus bottom of main tooth; intercostal tertiary veins slightly convex-percurrent; marginal tertiary veins form large loops which enclose small loops of quaternary veins; 1 to 3 thin veins from marginal loops entering sinus bottom of minute teeth; margin remotely serrate with glandular small teeth; intercostal quaternary veins reticulate; highest order veins sixth; areolation irregularly sized, intruded by three times branching veinlets. These features indicate that the fossil leaves are closely related to some leaves of *Alnus*, especially of the subgenus *Clethropsis* (Spach) Regel. The

Plate 2. (All figures in natural size unless otherwise stated)

Fig. 1. *Alnus* sp., NSM-PP 10379. ×2.
Figs. 2, 3. *Alnus prenepalensis* HU et CHANEY, NSM-PP 10377, 10378.
Fig. 4. *Carya* sp., NSM-PP 10383.
Figs. 5, 6. *Pterocarya* sp., NSM-PP 10381, 10382.
Figs. 7, 9. *Ulmus* sp. cf. *U. carpinoides* GOEPPERT, NSM-PP 10371, 10372.
Fig. 8. *Stewartia* sp., NSM-PP 10386.
Figs. 10, 11. *Eurya* sp., NSM-PP 10384, 10385.

Noda specimens are referable to *A. prenepalensis* originally described from the Miocene Shanwang flora of China (HU and CHANEY, 1938); although the secondary veins were illustrated to be craspedodromous by them, the description is valid. *A. prenepalensis* is closely similar to the extant *A. nepalensis* D. DON of South China and Himalaya region and *A. nitida* ENDL. of Himalaya and India.

Leaves noted in the above synonymy list are included in *A. prenepalensis* by their venation and marginal features. It is noteworthy that this species is commonly found in both the Ainoura Formation of Kyushu and the Hioki Group of Yamaguchi Prefecture.

Collection: NSM-PP 10377, 10378.

Alnus sp.

(Pl. 2, fig. 1)

Discussion: This small obovate leaf has finely serrate margin with glandular teeth. The secondary veins diverging at acute angles are 6 in pairs, and craspedodromous. The marginal tertiary veins enter teeth, and intercostal tertiary veins are convex-percurrent, nearly perpendicular to the midvein. This fossil represents a young leaf of *Alnus*, which is closely related to the extant *Alnus serrulatoides* CALL. of central and southern Japan.

Collection: NSM-PP 10379.

Genus ***Carpinus*** L.

Carpinus sp.

(Pl. 1, fig. 5)

Discussion: Several incomplete leaves are referable to the genus *Carpinus* by the following features: serrate margin with acuminate teeth, craspedodromous secondary veins, closely spaced tertiary veins, and single freely ending veinlets. The intersecondary smaller teeth are typically 2 in smaller leaves, while they are 2 to 4 in larger ones. However, the incompleteness of the specimens does not allow them to become name-bearing specimens.

Collection: NSM-PP 10380.

Family Juglandaceae

Genus ***Carya*** Nutt.

Carya sp.

(Pl. 2, fig. 4)

Discussion: The asymmetric shape, sessile feature, and combination of craspedodromous and camptodromous forking secondary veins indicate that this fossil is a

lateral leaflet of *Carya*. The fossil may represent an immature or a basal lateral leaflet, because it is smaller than the averaged leaflets of the extant *Carya*.

Collection: NSM-PP 10383.

Genus ***Pterocarya*** Kunth.

Pterocarya sp.

(Pl. 2, figs. 5, 6)

Discussion: A single fragmentary specimen represents a leaflet in the arcuate midvein and asymmetric form. The features that the teeth are adapically oriented, and that secondary veins markedly arise up along the margin to form a series of loops, indicate that this specimen is referred to *Pterocarya*. Tertiary leaflets of Juglandaceae of Japan have been considerably confused in taxonomy, although some of them were recently revised by the junior author (UEMURA, 1988). The incompleteness of this specimen does not allow to compare with *Pterocarya* leaflets which have been described in Japan.

Collection: NSM-PP 10381, 10382.

Family Theaceae

Genus ***Eurya*** THUNB.

Eurya sp.

(Pl. 2, figs. 10, 11)

Discussion: The thick, short petiole, small glandular-tipped teeth on the middle and apical margin, and thin secondary veins forming angular loops indicate that these small leaves are referable to *Eurya*. However, the thick texture of these specimens had obscured the distinct venation features, and thus the generic reference is not secure.

Collection: NSM-PP 10384, 10385.

Genus ***Stewartia*** L.

Stewartia sp.

(Pl. 2, fig. 8)

Discussion: This fossil leaf is referable to *Stewartia* by the following features: the remotely serrate margin with expanded, glandular-tipped teeth, camptodromous secondary veins that are irregularly spaced and markedly arising up, and thin convex-percurrent tertiary veins. The fossil is similar to *S. okutui* TANAI, which is related to the extant *S. pseudo-camellia* MAXIM. of central and southern Japan. However, the poor preservation does not allow its specific determination.

Collection: NSM-PP 10386.

Family Salicaceae

Genus *Populus* L.

Populus eowightiana (ENDO) TANAI et UEMURA, comb. nov.

(Pl. 3, figs. 1, 2)

Ficus eowightiana ENDO. 1964. Proc. Jap. Acad., 40(6): 419, figs. 1, 2. —ENDO. 1968. Bull. Natn. Sci. Mus., Tokyo, 11: 428, pl. 12, figs. 1, 2.
Broussonetia imaii ENDO. 1968. Bull. Natn. Sci. Mus., Tokyo, 11: 427, pl. 11, figs. 1, 2.

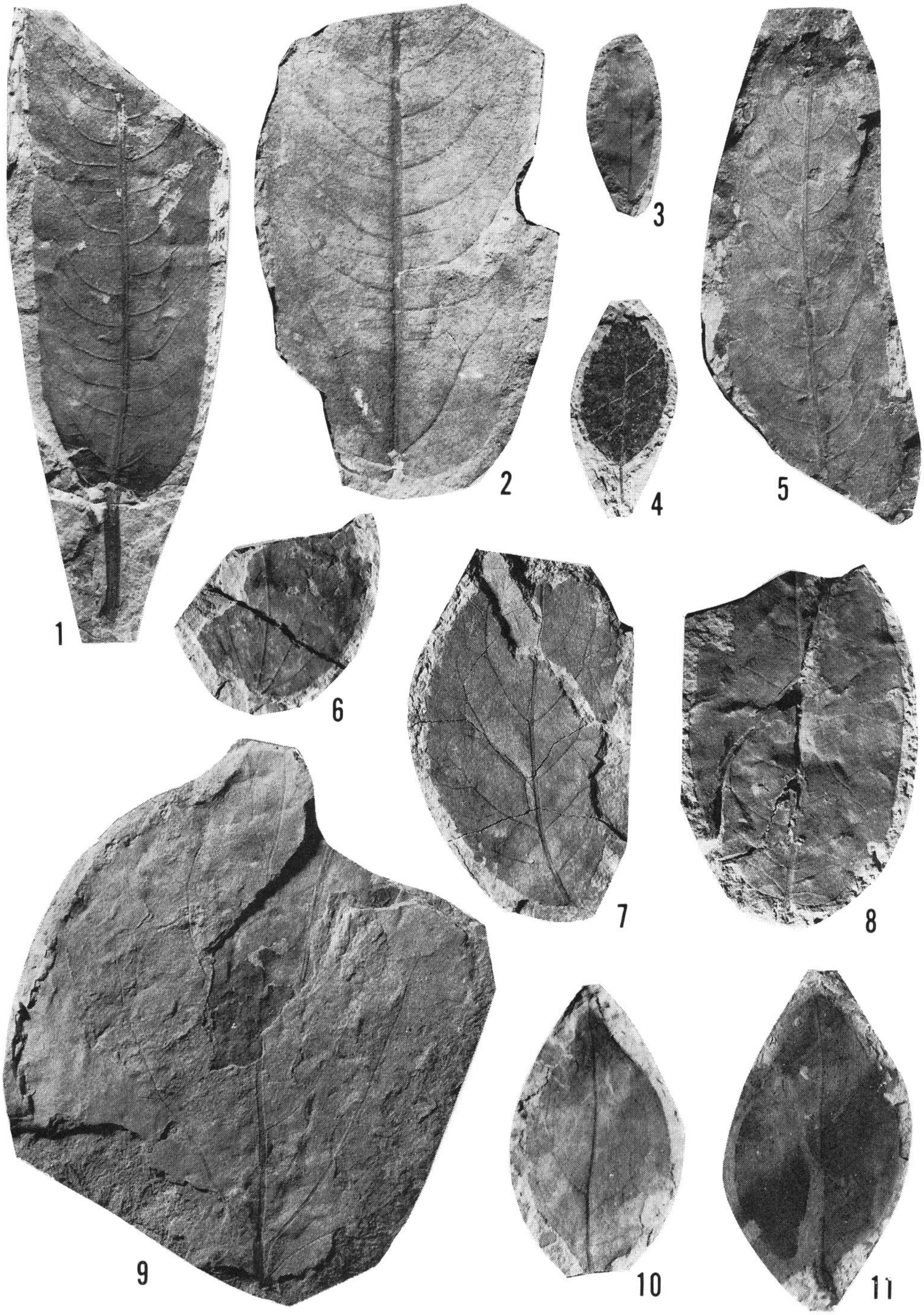
Typus: Holotype NSM 10485 (=NSM-PP 1801): Kakuta coal mine, Kuriyama-cho, Hokkaido; Ikushunbetsu Formation (early Late Eocene).

Emended Description: Leaves lanceolate to narrow ovate, acute to attenuate at apex, acute to obtusely rounded at base; 7.6 to 14.0 cm long and 2.0 to 6.5 cm wide, length/width ratio 2.2 to 4.3; margin finely serrate with incurved, glandular teeth: petiole rather slender, grooved, less than 1 mm thick, more than 4 cm long; a pair of glands existing on top of petiole. Venation pinnate; primary veins stout; secondary veins eucamptodromous, 6–8 or more in number, somewhat irregularly spaced, diverging at 45–80° except for basal pair which is usually less than 30–40°; basal secondaries emerging from base, giving off obliquely several tertiary veins that form a series of marginal loops; all the secondary veins gently arched, ascending along the margin, distal part of them becoming thinner and flexuous, forming a series of quadrangular loops with marginal tertiary veins; slender intersecondary veins nearly parallel to secondaries, emerging to tertiaries at middle part; intercostal tertiary veins thin but prominent, nearly straight or somewhat flexuous, perpendicular to secondaries; quaternary slender veins emerging from marginal loops, ending in teeth; intercostal quaternary veins reticulate; highest order venation sixth or seventh; areloes irregular, four or five sided, 0.3–0.5 mm across; ultimate veinlets thin, 3 or 4 times branching.

Discussion: The reinvestigation of the holotype specimen of *Ficus eowightiana* from the Eocene of Hokkaido (ENDO, 1964) reveals that it has finely serrate margin, with incurved and glandular teeth, although Endo mistook it to be entire. Many leaves identical to this species are found in the Ishikari Group of Hokkaido by the senior author. These leaves are referable to *Populus* by the following characters:

Plate 3. (All figures in natural size unless otherwise stated)

Figs. 1, 2. *Populus eowightiana* ENDO, NSM-PP 10387, 10388.
Fig. 3. *Leguminosites* sp., NSM-PP 10397. ×1.4.
Fig. 4. *Rosa usyuensis* TANAI, NSM-PP 10395.
Fig. 5. *Salix* sp., NSM-PP 10390.
Fig. 6. *Cercidiphyllum* sp., NSM-PP 10366.
Fig. 7. *Rosa okamotoi* TANAI et UEMURA, holotype NSM-PP 10394.
Fig. 8. *Sophora miojaponica* HU et CHANEY, NSM-PP 10396.
Fig. 9. *Populus* sp. cf. *P. balsamoides* GOEPPERT, NSM-PP 10389.
Fig. 10. *Rhododendron hekiense* TANAI et UEMURA, holotype NSM-PP 10391. ×2.
Fig. 11. *Rhododendron* sp., NSM-PP 10392. ×2.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glandular teeth, eucamptodromous secondary veins, basal secondary veins aparallel to other secondaries, profusely branching veinlets in small areoles, and a pair of glands in apical part of petiole. The above-noted description was based on our collection of Hokkaido, including the holotype. A leaf specimen originally described as *Broussonetia imaii* from same locality of the holotype (ENDO, 1968) is inseparable from *Populus eowightiana* here emended. Several leaves from the Noda flora are identical to *P. eowightiana* in all characters.

P. eowightiana is the common species through the Paleogene Ishikari Group, especially abundant in the Ikushunbetsu Formation. This species is similar to *P. crassa* (LESQ.) COCKERELL of the Oligocene Florissant flora of Colorado (MACGINITIE, 1953) and *P. cinnamomoides* (LESQ.) MACGINITIE of the Eocene Green River flora of Colorado and Utah (MACGINITIE, 1969), but Japanese species is distinguished from the former by less secondary veins and from the latter by densely serrate teeth. These three fossil species may be related to some extant species of the section Tacamahacea Spach in general foliar shape, margin and secondary venation features, especially to *P. laurifolia* LEBED. of northeastern Asia and *P. angustifolia* RYDBERG of North America.

Collection: NSM-PP 10387, 10388.

Populus sp. cf. ***P. balsamoides*** GOEPPERT

(Pl. 3, fig. 9)

cf. *Populus balsamoides* GOEPPERT. 1855. Tert. Fl. Schoss. Shlesien, p. 23, pl. 15, figs. 5, 6.

Discussion: The features of marginal glandular teeth and small areolation indicate that this fossil leaf is referable to *Populus*, and is probably identical to *P. balsamoides*.

Collection: NSM-PP 10389.

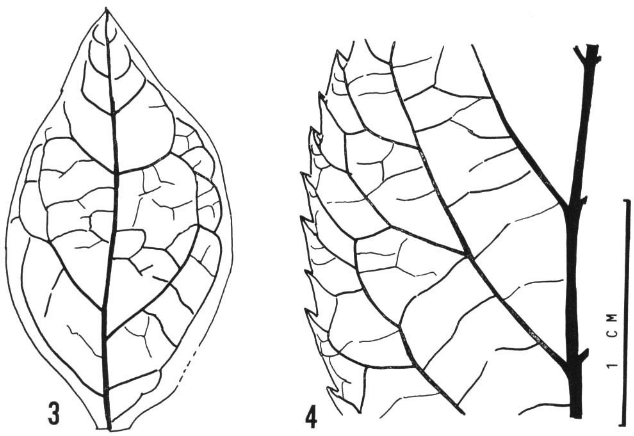
Genus ***Salix*** L.

Salix sp.

(Pl. 3, fig. 5)

Discussion: The numerous eucamptodromous secondary veins, 2 or 3 distinct intersecondary veins per the secondary, and finely serrate margin are features of *Salix*. A specimen described as *Juglans nipponica* from the Miocene of Hokkaido (TANAI, 1961: pl. 6, fig. 9) is referable to *Salix* as already pointed out by UEMURA (1988), and it resembles the Noda specimens. These fossil leaves, however, are too ill-preserved to give a specific diagnosis.

Collection: NSM-PP 10390.



Figs. 3, 4. Venation of *Rhododendron* and *Rosa*. 3, *Rhododendron hekiense* TANAI et UEMURA, sp. nov., holotype NSM-PP 10391; 4, *Rosa okamotoi* TANAI et UEMURA, sp. nov., holotype NSM-PP 10394.

Family Ericaceae

Genus ***Rhododendron*** L.

Rhododendron hekiense TANAI et UEMURA, sp. nov.

(Pl. 3, fig. 10; Fig. 3)

Typus: Holotype NSM-PP 10391; Noda, Heki-cho, Yamaguchi Pref.; Kiwado Formation (Late Oligocene).

Diagnosis: Leaf small, narrow ovate, 2 cm long and 1 cm wide; apex acute with mucronate tip; base decurrent; margin entire; petiole missing. Midvein thick, secondary veins five in pairs, irregularly spaced, diverging at variable angles, curving up abruptly near margin, joining the superadjacent secondary at right angle; intercostal tertiary veins reticulate; marginal tertiary veins forming large loops along margin; the higher order venation ill-preserved.

Discussion: The mucronate apex, ducurrent base and irregularly spaced, camptodromous secondary veins indicate that this small leaf is referable to *Rhododendron*. *R. hekiense* is similar in the venation feature to the extant *R. simsii* PLANCHON living in southern Japan and South China.

Collection: Holotype NSM-PP 10391.

Rhododendron sp.

(Pl. 3, fig. 11)

Discussion: This small leaf is referable to *Rhododendron* in mucronate apex and venation features. It is distinguishable from *R. hekiense* in the following char-

acters: the acute apex and base, and 7 pairs of the secondary veins arising up along the margin, and irregularly percurrent tertiary veins. This fossil leaf is similar to the extant *R. semibarbatum* MAXIM. of Japan in venation features. However, it is too poor in preservation to render a specific diagnosis.

Collection: NSM-PP 10392.

Family Ebenaceae

Genus ***Diospyros*** L.

Diospyros miokaki HU et CHANEY

(Pl. 4, fig. 1)

Diospyros miokaki HU et CHANEY, 1938. Paleont. Sinica, [A], (1): 72, pl. 46, figs. 1, 2 (excluding fig. 3).

Discussion: Of the three original specimens illustrated as *Diospyros miokaki* by HU and CHANEY (1938), one specimen (pl. 46, fig. 3) is excluded from *Diospyros* by regularly-spaced secondary veins and closely spaced tertiary veins. The markedly arising irregularly spacing of the secondary veins and transverse secondary veins indicate that the Noda spccimen is referable to *D. miokaki*.

Collection: NSM-PP 10393.

Family Rosaceae

Genus ***Rosa*** L.

Rosa okamotoi TANAI et UEMURA, sp. nov.

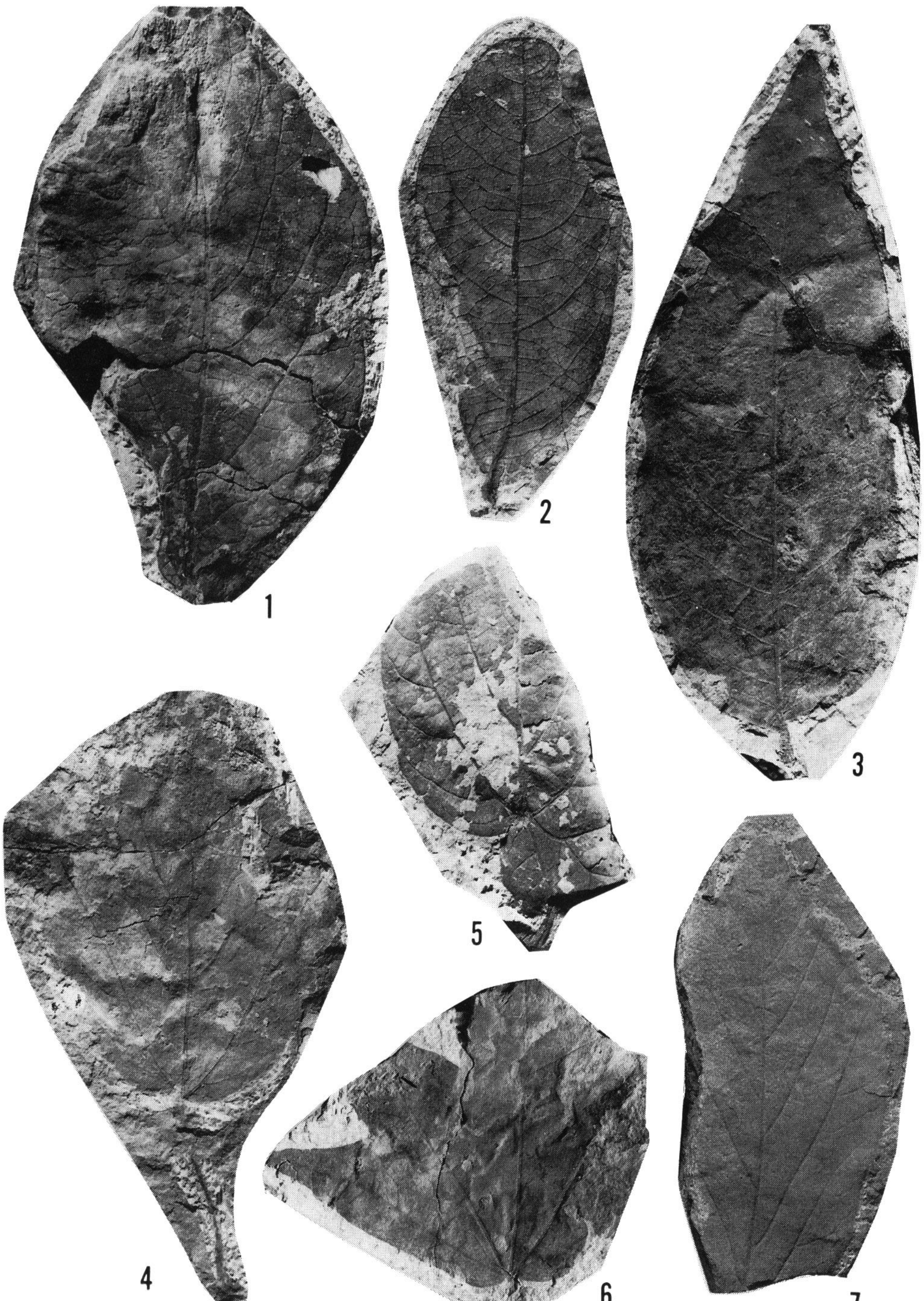
(Pl. 3, fig. 7; Fig. 4)

Typus: Holotype NSM-PP 10394; Noda, Heki-cho, Yamaguchi Pref.; Kiwado Formation (Late Oligocene).

Diagnosis: Leaflet somewhat inequilateral, elliptic, 5.5 cm long (estimated) and 2.8 cm wide; base obtuse; apex missing; margin serrate; teeth acute with glandular pointed tip (tooth type C1 or C2); petiolule missing. Venation pinnate; midvein thick; secondary veins 8 or 9 (estimated) in opposite pairs, diverging at acute angles, gently curving up, camptodromous; 3 or 4 subsecondary veins from the secondary diverging at acute angles to form large loops; intercostal tertiary veins thin, irregularly percurrent; marginal tertiaries diverging from large loops, entering teeth centrally;

Plate 4. (All figures in natural size)

Fig. 1. *Diospyros miokaki* HU et CHANEY, NSM-PP 10393.
Fig. 2. *Lagerstroemia imamurae* TANAI et UEMURA, holotype NSM-PP 10398.
Fig. 3. *Sapindus tanaii* ONOE, NSM-PP 10400a.
Fig. 4. *Acer* sp. cf. *A. tricupidatum* BRONN, NSM-PP 10400b.
Fig. 5. "*Alangium*" *aequalifolium* (GOEPPERT) KRYSHTOFOVICH et BORSUK, NSM-PP 10401.
Fig. 6. *Acer rotundatum* HUZIOKA, NSM-PP 10399.
Fig. 7. *Hamamelis* sp. cf. *H. protojaponica* TANAI et N. SUZUKI, NSM-PP 10368.



higher order veins indistinct.

Discussion: The marginal loops of secondary and subsecondary veins, and serrate margin with acute and glandular-tipped teeth are features of Rosaceae. The arcuate midvein and asymmetric shape indicate that this specimen represents a lateral leaflet of *Rosa*. No fossil rose species is comparable to this fossil in the Tertiary of East Asia; all fossil leaflets of *Rosa* described earlier are further smaller than this fossil.

This species is named in recognition of Professor Kazuo OKAMOTO who has devoted much time for geology and paleontology of the Yuya-wan area.

Collection: Holotype NSM-PP 10394.

Rosa usyuensis TANAI

(Pl. 3, fig. 4)

Rosa usyuensis Tanai. 1961. J. Fac. Sci. Hokkaido Univ. [4]. 11: 343, pl. 24, figs. 5, 6, 9.

Discussion: The thin secondary veins forming angular loops from which tertiary veins enter acute teeth, more than twice branching veinlets, and long petiole (petiolule) indicate that this small specimen is a terminal leaflet of *Rosa usyuensis*.

Collection: NSM-PP 10395.

Family Fabaceae

Genus ***Leguminosites*** BOWERBANK

Leguminosites sp.

(Pl. 3, fig. 3)

Discussion: The specimen, having inequilateral base and thickened short petiolule, represents a legume leaflet. Striking are the features that numerous weak secondary veins diverge from the primary vein at obtuse angles and run parallel to each other. The fossil shows the resemblance with leaflets of *Lespedeza*.

Collection: NSM-PP 10397.

Genus ***Sophora*** L.

Sophora miojaponica HU et CHANEY

(Pl. 3, fig. 8)

Sophora miojaponica HU et CHANEY, 1938. Palaeont. Sinica, [A], (1): 53, pl. 27, figs. 1, 3.

Discussion: The short, thick petiolule, camptodromous secondary veins and irregular tertiary veins are features of some lugume leaflets. These fossils are referable to *Sophora miojaponica* in foliar shape.

Collection: NSM-PP 10396.

Family Lythraceae

Genus ***Lagerstroemia*** L.

Lagerstroemia imamurae Tanai et Uemura, sp. nov.

(Pl. 4, fig. 2)

Typus: Holotype NSM-PP 10398; Noda, Heki-cho, Yamaguchi Pref.; Kiwado Formation (Late Oligocene).

Diagnosis: Leaf oblong, rounded at apex, acute at base, 6.2 cm long and 2.6 cm (estimated) wide; margin entire, revolute with thickening; petiole stout, 4 mm long and 1.8 mm thick; texture thick, coriaceous. Venation pinnate; midvein thick; secondary veins 9 in subopposite pairs, brochidodromous, irregularly spaced (closer on the apical and basal parts than on the middle), diverging at 70–80° on the middle and apical parts and at 40–55° on the basal part, curving up, joining superadjacent secondary vein at right angle; 1 intersecondary vein sometimes present; intercostal tertiary veins irregularly percurrent with 3–4 mm distance, or departing from midvein at right angle and then bending basally to the secondary; marginal tertiary veins forming loops which enclose quaternary arches just within margin; intercostal quaternary veins forming large quadrangular meshes; areoles 4- or 5-sided, intruded by several times branching veinlets.

Discussion: In the thich texture, oblong shape, well-defined brochidodromous secondary veins and marginal tertiary looping feature, this fossil leaf resembles those of some genera of Myrtaceae, Combretaceae, Euphorbiaceae and Capparidaceae. However, the irregularly spacing of secondary veins and intercostal venation features exclude this fossil from the above families. The fossil shows a close similarity in venation to leaves of the extant *Lagerstroemia indica* L. of Central China and *L. speciosa* PERS. of India to New Guinea, especially to the latter. The quadrangular areoles that are intruded by profusely branching veinlets make the generic reference of fossil obscure. There is no fossil species of East Asia comparable to *L. imamurae*.

This species is named in honor of Professor Emeritus Sotoji IMAMURA, who rendered much important contribution to Tertiary geology of western Honshu.

Collection: Holotype NSM-PP 10398.

Family Sapindaceae

Genus ***Sapindus*** L.

Sapindus tanaii ONOE

(Pl. 4, fig. 3)

Sapindus tanaii ONOE, 1974. Geol. Surv. Jap. Rept. (253): 52, pl. 12, figs. 5–7, text-fig. 3.

Discussion: The asymmetric shape, entire margin, eucamptodromous slender secondary veins and well-developed intersecondary veins indicate that this fossil represents a lateral leaflet of *Sapindus tanaii* ONOE which is closely related to the extant

S. mukurossi GAERTN. of Japan.

Collection: NSM-PP 10400a.

Family Aceraceae

Genus *Acer* L.

Acer rotundatum HUZIOKA

(Pl. 4, fig. 6)

Acer rotundatum Huzioka, 1943, J. Fac. Sci., Hokkaido Univ., [4], 7: 129. pl. 24, figs. 1–3; pl. 25, fig. 2. —TANAI, 1983. ditto, 20(4): 329, pl. 11, figs. 1, 3, 6 (see synonymy and discussion).

Discussion: This species, represented by five-lobed and entire-margined leaves, is one of the most common maples in the Tertiary of East Asia. *Acer rotundatum* is also commonly found in the Jyuraku and Hitomaru formations.

Collections: NSM-PP 10399.

Acer sp. cf. ***A. tricuspidatum*** BRONN

(Pl. 4, fig. 4)

cf. *Acer tricuspidatum* BRONN, 1838. Lethaea Geogn. 2. pl. 35, fig. 10a, b. —TANAI, 1983. J. Fac. Sci., Hokkaido Univ., [4], 20(4): 323, pl. 8, figs. 5, 7, 8 (see synonymy and discussion).

Discussion: The three basal actinodromous venation, a pair of basal secondary veins bifurcating to embrace the lobe sinus, quadrangular areoles that are intruded by a single veinlets, and long petiole are features of some species of *Acer*. The fossil leaf is probably referable to *A. tricuspidatum* BRONN which is closely related to the extant *A. rubrum* L., although it is poorly preserved in marginal feature.

Collection: NSM-PP 10400b.

Family Alangiaceae

Genus *Alangium* Lamark.

"***Alangium***" ***aequalifolium*** (GOEPPERT) KRYSHTOFOVICH et BORSUK

(Pl. 4, fig. 5)

Alangium aequalifolium (GOEPPERT) KRYSHTOFOVICH et BORSUK, 1939. Prob. Paleont. (5): 390, pl. 5, figs. 1–8; pl. 6, fig. 12.

Discussion: The markedly asymmetric shape, deeply cordate base, camptodromous secondary veins, and well-defined percurrent tertiary veins are characteristics of "*Alangium*" *aequalifolium*, which has been commonly reported from the Lower Miocene of Japan. The taxonomy of leaves having the above-noted features has been discussed by many authors (see, KNOBLOCH & KVAČEK, 1965 and TANAI, 1989). It was recently confirmed by TANAI (1989) that Paleogene leaves of the so-called "*Alangium*" are of diverse origin. Although the specimen here illustrated seems

to be referable to *Alangium* in having profusely branching veinlets in four sided areoles, its poor preservation cannot allow to give a full discussion for the taxonomic problem which has been debated up to the present.

Collection: NSM-PP 10401.

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